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28

1. INTRODUCTION

The Burst and Transient Source Experiment (BATSE) is one of four instruments on the Compton Observatory which was launched by the space shuttle Atlantis on April 5, 1991. BATSE was activated on April 16 and its burst trigger mode was enabled on April 21. Since then, BATSE has detected more than 300 gamma-ray bursts and more than 450 solar flares. Pulsed gamma-rays have been detected from more than a dozen sources and emission from a similar number of sources has been detected by the Earth occultation technique. The daily BATSE operations tasks represent a substantial level of effort and involve a large team which includes MSFC personnel as well as contractors such as UAH. The effort is naturally divided into several areas: data operations, burst operations, occultation operations, and pulsar operations. UAH personnel are involved to some extent in all of these as well as contributing to various areas of scientific data analysis.

2. MISSION OPERATIONS

T. Koshut, R. Mallozzi, G. Pendleton, and W. Paciesas performed burst operations regularly. M. Flickinger performed data operations several times per week until September 1991. Flickinger was also responsible for maintenance of the MOPS SPHIST software. Paciesas served as BATSE Mission Operations (MOPS) Software Development Manager and also chaired the Level V Configuration Control Board for the MOPS software. P. Moore served as MOPS software librarian until August 1991 and was responsible for coding and/or maintenance of several MOPS programs: DSHIST, GET_DATA, CCHECK, CPUM, and OHEDITOR..

Under subcontract to UAH, W. Henze (Teledyne-Brown) provided assistance in BATSE mission operations activities. Principal areas of support included scheduling and coordination of data operations, development of operations procedures, and data archiving.

Paciesas headed the BATSE Occultation Analysis team for Mission Operations and helped coordinate the effort to develop enhanced occultation analysis software [1,2]. The MOPS occultation analysis software has performed admirably and interesting results have been obtained on various sources, including the Crab Nebula, Cygnus X-1, GX339-4, Cen A, and the Galactic Center [3-6].

3. DATA ANALYSIS

Pendleton led the joint UAH/MSFC effort to develop response matrices for the BATSE large-area detectors (LADs) and spectroscopy detectors (SDs). The primary areas of concern at this point are the atmospheric scattering corrections and the LAD angular response at large angles. Pendleton developed software to calculate atmospheric scattering contributions using a parametrization of previously computed Monte Carlo simulations. Validation of these calculations and the LAD angular response began with studies by Pendleton and M. Brock (MSFC) of locations of known solar flares as derived by BATSE. Initial results [7-9] were used to refine the angular response of the LADs. Corrections to the response near 90° are clearly significant. The study was expanded in scope in February 1992 as the Burst Location Optimization Project, headed by Pendleton with assistance from Brock and M. Stollberg. The project will attempt to consider all systematic effects which affect burst localization by studying a large data base of solar flares detected by BATSE. Efforts to date have concentrated on assembly of the data base and development of a version of the burst location software which can easily be modified to investigate the systematic effects.

Paciesas coordinated BATSE spectral analysis efforts among UAH, MSFC, GSFC, and UCSD. Builds of BSAS were distributed by GSFC in April 1991, July 1991, September 1991 and January 1992. A description of BSAS was published [10]. Spectral results on bursts were presented at the Huntsville Burst Workshop [11,12]. Paciesas and Pendleton collaborated with B. Schaefer (GSFC) and others on a paper describing high-energy spectral breaks in bursts [13].

Paciesas and Pendleton worked with D. Band (UCSD) to improve the channel-to-energy conversion algorithm. Work concentrated primarily on the SDs. Band developed a methodology which relied on modeling the physical and electronic processes involved as opposed to the empirical algorithm used previously. Band's revised algorithm was incorporated into build 7 of BSAS by GSFC personnel. Paciesas defined revisions to the IBDB format to include additional information for use with the new algorithm and supervised the resulting modifications to the MOPS program SDBGEN. Pendleton and M. Briggs produced a version of the MOPS program SPHIST which includes the revised algorithm. Pendleton also worked with Briggs to improve the robustness of spectral line fitting in SPHIST.

Paciesas studied hardness ratios of bursts in an attempt to find correlations between hardness and intensity [14,15]. Paciesas and Pendleton collaborated with MSFC personnel on analysis of burst spatial distributions [16-22]. Paciesas and Pendleton worked with C. Kouveliotou (MSFC), J. Norris (GSFC) and others on temporal analysis of gamma-ray burst light curves [23-25]. Paciesas collaborated with P. N. Bhat (MSFC) and others on temporal studies of a particularly short burst [26]. Paciesas collaborated with K. Hurley (UC Berkeley), T. Cline (GSFC), C. Kouveliotou (MSFC) and others on high-precision burst locations using the interplanetary network [27-29]. Paciesas collaborated with J. Horack (MSFC) and others on a study of electron precipitation events detected by BATSE [30].

4. OTHER ACTIVITIES

Paciesas presented invited talks on "Preliminary Results from the GRO/BATSE" at the 22nd International Cosmic Ray Conference in Dublin, Ireland, during August 11-23, 1991, and on "GRO/BATSE results on variability and activity states of black hole candidates" and "BATSE burst observations" at the Workshop on X-Ray and Gamma-Ray Signatures of Black Holes vs. Neutron Stars in Aspen, CO, during January 19-25, 1992. Paciesas (as co-chair) and Pendleton served on the organizing committee for the Huntsville Burst Workshop at UAH during October 16-18, 1992. Koshut, Mallozzi, and Stollberg also attended. Paciesas and Pendleton attended the Second GRO Science Workshop in Annapolis, MD, during September 23-25, 1991. Koshut, Mallozzi, Stollberg, Paciesas, and Pendleton attended the 179th American Astronomical Society Meeting in Atlanta, GA, during January 12-16, 1992.

Paciesas continued to serve as the BATSE representative on the *Compton* Users' Committee, attending meetings in July 1991, November 1991, and March 1992. Paciesas provided BATSE inputs for the Phase 2 Guest Investigator Program Research Announcement [31] which was issued in September 1991.

Support for the study of ionospheric disturbances by high-energy astrophysical phenomena was provided as needed. Flickinger had primary responsibility for monitoring the VLF receiving station at MSFC, collecting data, and providing charts for cross-correlation with GOES data.

Copies of publications involving UAH personnel as principal author are attached.

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ATTACHMENTS

PRELIMINARY CALIBRATION RESULTS FOR THE BATSE INSTRUMENT ON CGRO

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BATSE Science Team

ABSTRACT

Preliminary results pertaining to spectral reconstruction using BATSE Large Area Detector measurements of solar flares will be presented. These solar flare measurements are currently being used to fine tune the calibration of our data analysis software. The current status of the stability of spectral analysis given the systematic errors present in burst location at the time of the writing of this paper discussed. A brief description of enhancements to the input data for the atmospheric scattering algorithm that will be implemented in the data analysis software is presented.

SOLAR FLARE SPECTRAL MEASUREMENTS

Power law fits to a strong solar flare occurring May 30 th at 09:37 UT using large area detector continuous data are presented here in order to show the variability in spectral intensity encountered when coping with location errors of 5°. The current solar flare location accuracy averages about 5°. Spectra are calculated for a location on the sun and for a set of four locations around the sun about 5° away from the sun position. At each location the detector response matrices (DRM's) are evaluated for each of the three brightest detectors. The response depends primarily on the angle between the source direction and the detector normal. For this flare the angles between the sun direction and the first, second, and third detectors are 34.4°, 53.1°, and 61.43° respectively. These angles change for the locations offset from the sun by 5° hence the corresponding DRM's generated at these locations are different. The fits are performed for 6 continuous channels covering the energy range 63-203 keV. The channel to energy conversion is most reliable in this range currently and the flare intensity is significant here as well.

Figure 1 shows power law fits to the data in the brightest detector convolved through the detector response matrix for that detector evaluated at each of the five assumed source directions. The spread in spectral intensity of 13% is due to the differences in the DRM's. Figures 2 and 3 show the same set of fits to the second and third brightest detectors respectively. The spread in intensity for these fits is 27% for the second brightest detector and 27% for the third brightest detector.

Figure 4 shows power law fits to the three brightest detectors' data convolved through the DRM's simultaneously. This gives the best fit to the total data set for each assumed flare location. The spread in spectral intensity for these fits is 5%. These fits are subject to the least variability due to the fact that as one moves the apparent source location some detectors see the flare more directly while others see it less directly. For a set of three detectors these effects tend to cancel out resulting in a fairly stable measurement of the source intensity over a 5° range in assumed source direction. As systematic errors in the detector response are identified and eliminated the errors on source location will decrease producing a corresponding decrease in the systematic errors in spectral analysis.

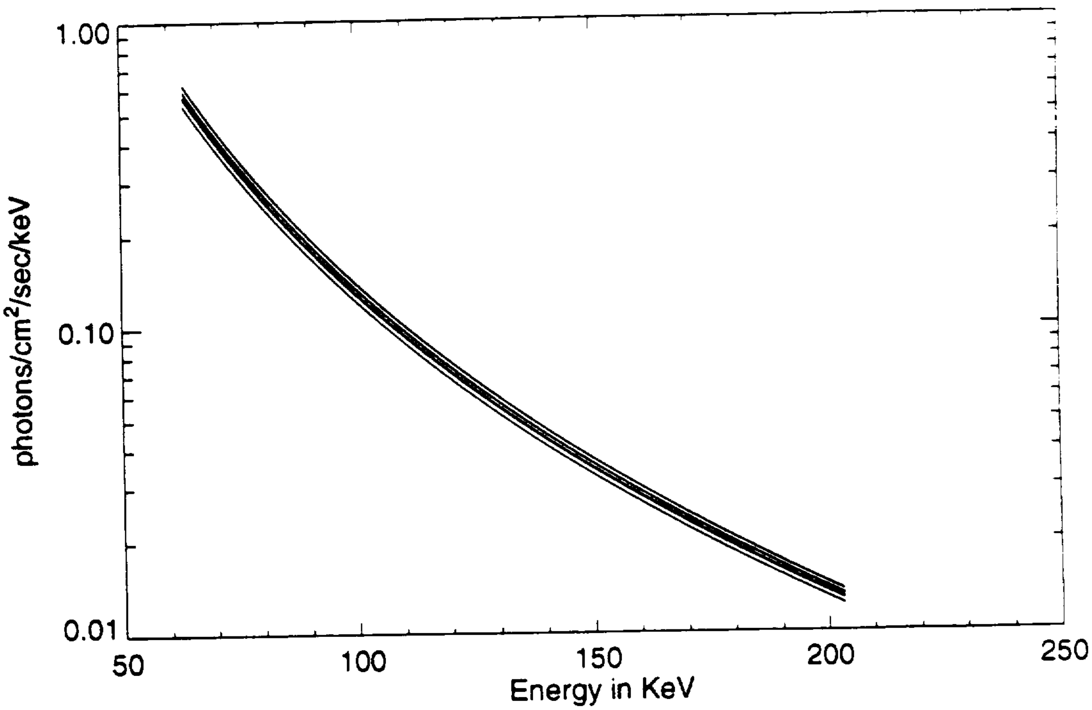

Figure 1: Power Law Fits to Brightest Detector

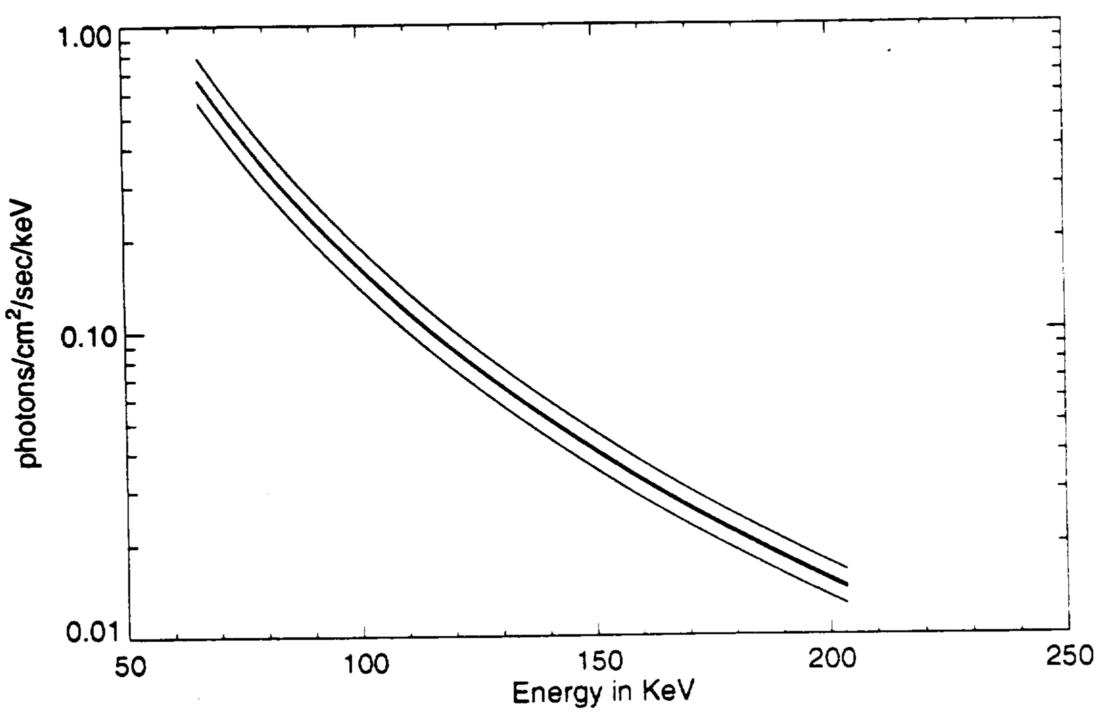

Figure 2: Power Law Fits to Second Brightest Detector

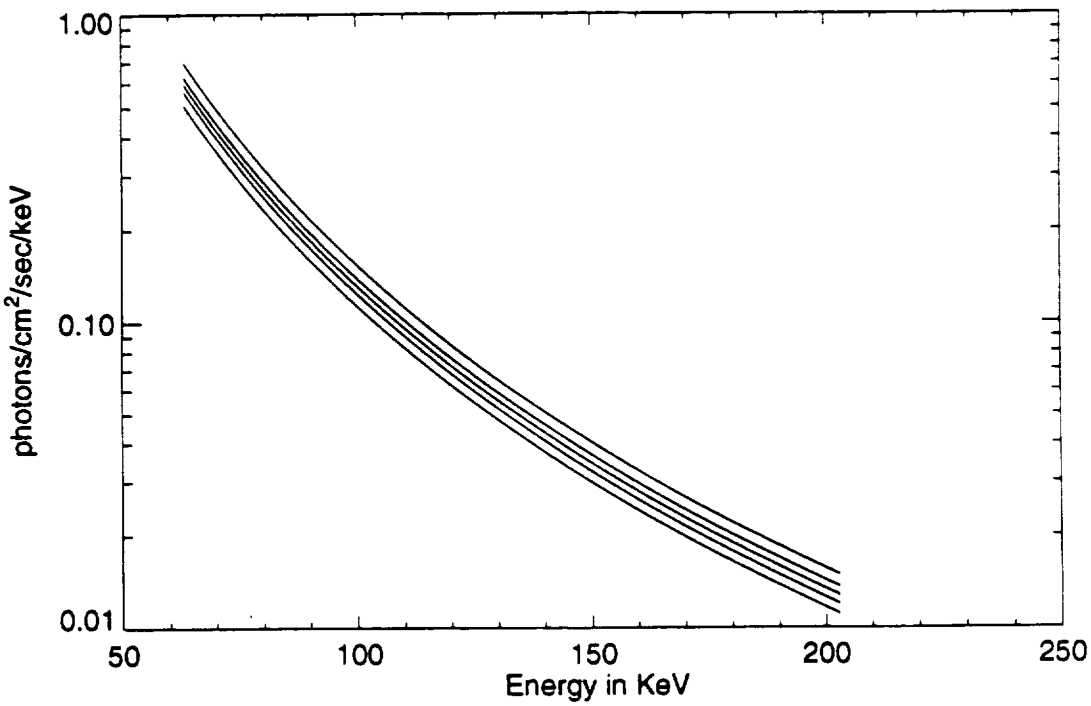

Figure 3: Power Law Fits to Third Brightest Detector

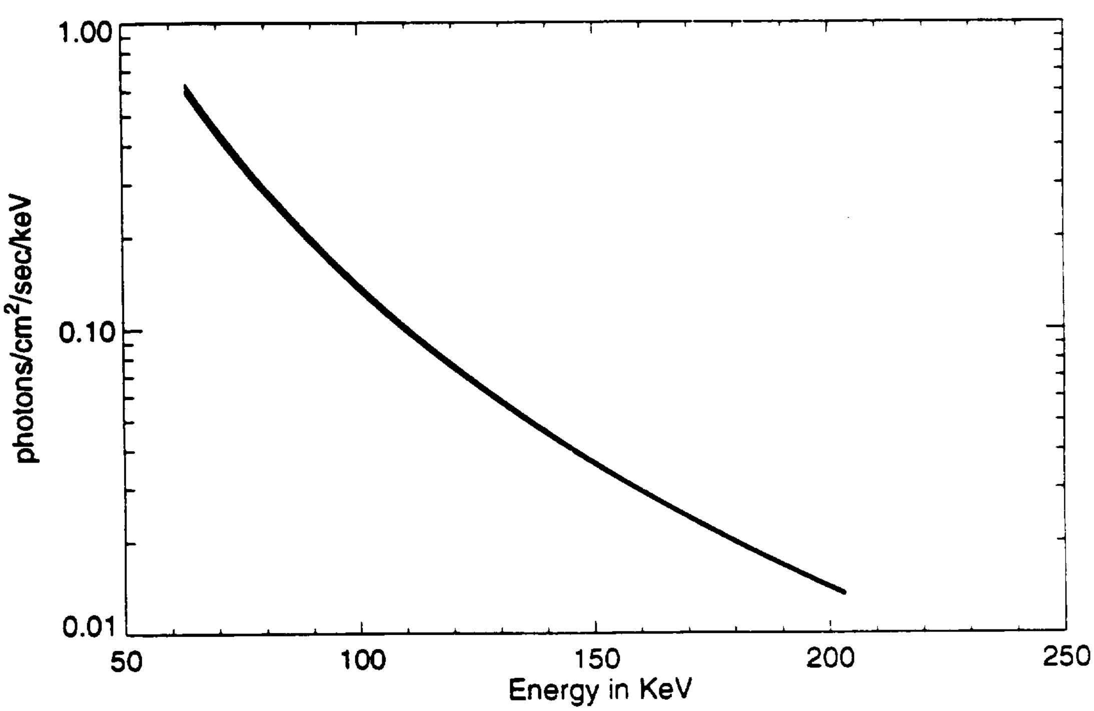

Figure 4: Power Law Fits to Three Brightest Detectors

ATMOSPHERIC SCATTERING

The atmospheric scattering algorithm currently employed in the burst location software calculates the scattered flux observed by a detector by numerically integrating an expression representing the single Compton scattering of photons off the earth into the detector. An atmospheric scattering algorithm has been created using the results of a Monte Carlo code that takes into account both single and multiple Compton scattering. This algorithm was used in the calculations performed above pertaining to solar flare intensity measurements. Figures 5 through 7 show spectra produced by the Monte Carlo code for monoenergetic plane waves of photons incident on the earth at a specific zenith angle of 60°. The spectra are for the photons collected at the spacecraft orbital altitude that have Compton scattered in the earth's atmosphere. Photoelectric absorption is also present in the simulation to account properly for the absorption of the lower energy photons. These figures show single scatter spectra for photons that have scattered only once in the atmosphere and multiple scatter spectra for photons that have scattered two or more times in the atmosphere before reaching orbital altitude. These results indicate that a significant number of the atmospherically scattered photons observed by the detectors have scattered two or more times in the atmosphere before hitting a detector.

At the time of the writing of this paper a data product incorporating these Monte Carlo results has been created and is ready for implementation into the burst location algorithm. The implementation of this algorithm should result in a significant decrease in the magnitude of our systematic errors.

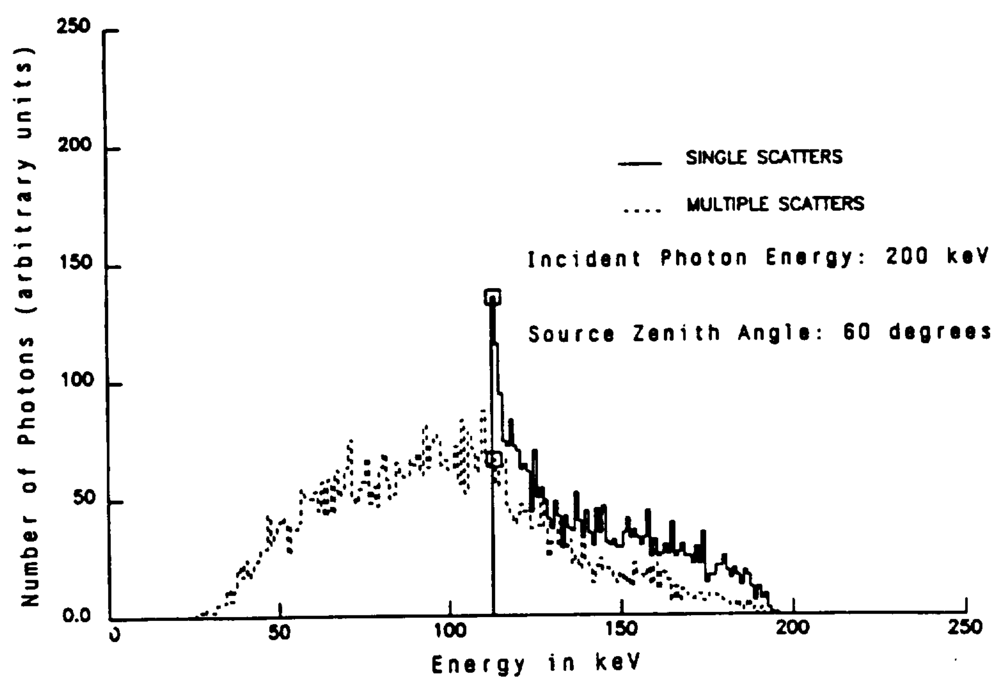

Figure 5: Energy Spectra of Collected Photons

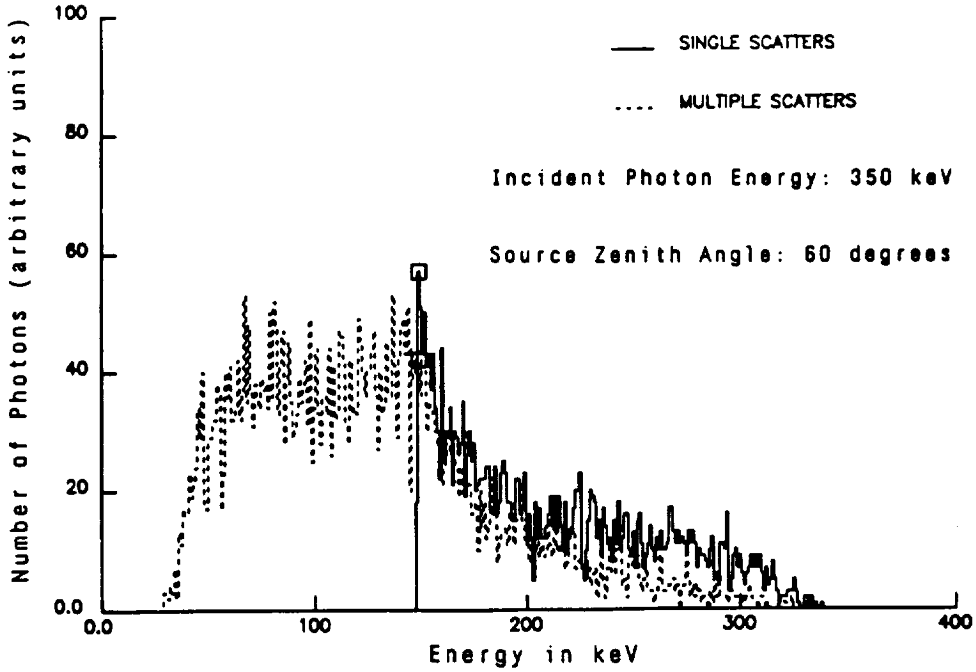

Figure 6: Energy Spectra of Collected Photons

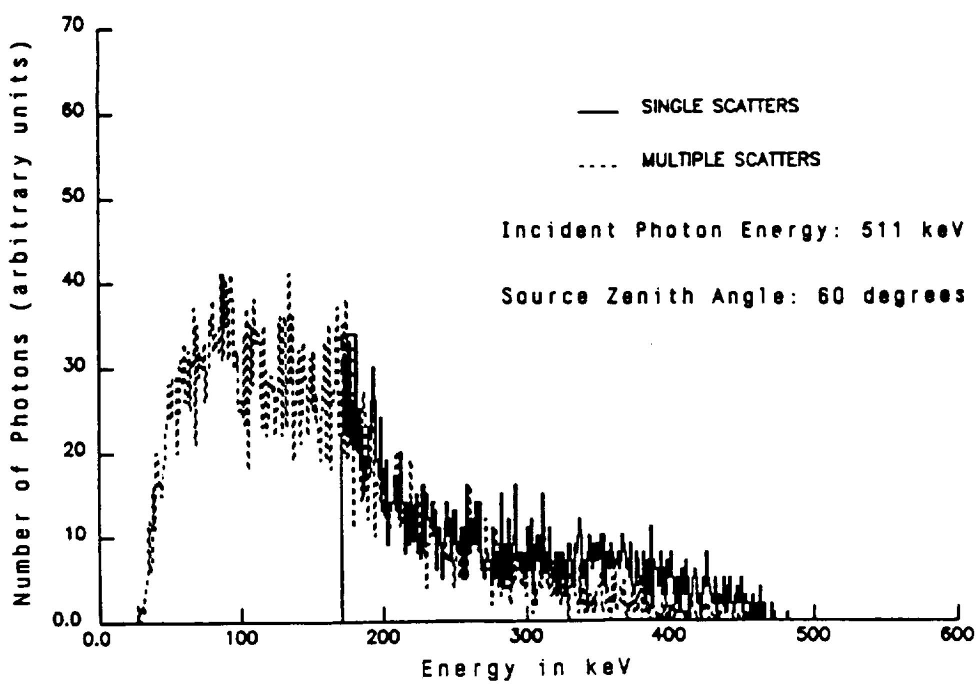

Figure 7: Energy Spectra of Collected Photons

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HARDNESS/INTENSITY CORRELATIONS AMONG BATSE BURSTS

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ABSTRACT

Conclusions about the nature of γ-ray bursts derived from the size-frequency distribution may be altered if a significant correlation exists between burst intensity and spectral shape. Moreover, if γ-ray bursts have a cosmological origin, such a correlation may be expected to result from the expansion of the universe. We have performed a rudimentary search of the BATSE bursts for hardness/intensity correlations. The range of spectral shapes was determined for each burst by computing the ratio of the intensity in the range 100–300 keV to that in 55–300 keV. We find weak evidence for the existence of a correlation, the strongest effect being present when comparing the maximum hardness ratio for each burst with its maximum rate.

INTRODUCTION

For some time, the opinion that γ-ray bursters originate on galactic neutron stars has been widely held (*e. g.*, ref. 1). However, recent measurements of the burst size-frequency distribution and sky distribution[2] are difficult to explain within this scenario, leading some researchers to reconsider cosmological models.[3] In such models, the existence of a spectral/intensity correlation is expected at some level simply from the cosmological redshift.[4] The lack of a correlation may provide limits on the possible range of redshifts of the burst sources. Recent studies[5,6] have presented evidence for such a correlation in bursts detected by less sensitive instruments than BATSE. The presence of a correlation is not in itself a confirmation of the cosmological model; however, if such a model were true, the effect should be more pronounced for weaker bursts since these would represent larger redshifts.

OBSERVATIONS

The Burst and Transient Source Experiment (BATSE) has been described in detail elsewhere.[7] It consists of eight identical modules located at the corners of the Compton Gamma Ray Observatory. The burst trigger criterion demands that at least two detectors simultaneously show a significant increase in the count rate above background on at least one of three independent timescales: 0.064 s, 0.256 s and 1.024 s. The trigger energy range is ~55–300 keV. Once a

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trigger has occurred, data of various types are accumulated for ~240 s into a 4 Mb memory which is later telemetered to the ground at a lower data rate. The detector gains are maintained in balance by on-board software which regularly adjusts the photomultiplier tube high voltages in response to changes in the peak location of the 511 keV background line.

For this preliminary investigation we elected to use the DISCSC data type which comprises combined rates from the triggered detectors with 0.064 s resolution in four energy bands. Our computed parameters were derived using only the two DISCSC energy bands which together span the trigger range: 55–100 keV and 100–300 keV. Since the analysis was preliminary, no corrections for detector response or atmospheric scattering were performed. Instead, the restriction of energy range and use of summed-detector data provide a means of reducing systematic errors while minimizing complexity of analysis.

Our sample consists of 126 BATSE triggered bursts occurring between April 21 and September 23, 1991. For each of these, we subtract a quadratic background and compute rate histories in each band with either 0.064 s, 0.256 s, or 1.024 s time resolution.* For each time interval i we compute the hardness ratio H_i as

$$H_i = R_{i,2}/(R_{i,1} + R_{i,2}),$$

where $R_{i,1}$ and $R_{i,2}$ are the rates in the 55–100 and 100–300 keV bands, respectively. We define a maximum hardness ratio $H_{\mathbf{max}}$ for each burst as

$$H_{\mathbf{max}} = \max(H_i).$$

We also compute an "average" hardness ratio H for each burst as

$$\overline{H} = \sum_i (R_{i,2}\Delta t_i) \Big/ \sum_i ((R_{i,1} + R_{i,2})\Delta t_i).$$

We look for possible correlations between $H_{\mathbf{max}}$ or $\overline{H}$ and either the peak rate in the triggering energy range $R_{\mathbf{max}} = \max(R_{i,1} + R_{i,2})$ (which is a rough estimate of the peak flux) or the total counts $N_{\mathrm{tot}} = \sum_i (R_{i,1} + R_{i,2})$ (which is a rough estimate of the fluence).

Figure 1 shows correlation plots of $H_{\mathbf{max}}$ and H versus $R_{\mathbf{max}}$ and N, respectively, for the entire sample of 126 bursts. The first row of Tables I and II summarizes the correlation coefficients and chance probabilities for each case. As expected, there is considerable scatter in the data. Nevertheless, there is evidence for a correlation between hardness ratio and maximum rate, whereas the correlation with total counts is not significant. For the shortest duration bursts ($\lesssim 0.3$ s), spectral and intensity changes are often predominant on shorter timescales than the DISCSC resolution. Since this data limitation adversely affects our ability to measure the maximum rate, we identified 30 such events and analyzed them separately. The correlation coefficients and chance probabilities for these events are summarized in the second row of Tables I and II; no significant correlation is present.

Carrying the analysis further, we separately investigated another class of events, single pulses without significant temporal substructures, which had been

* The selection of time resolution for a particular burst was based on visual inspection. Where necessary, the basic 0.064 s data were summed until statistically significant structure could be seen in the light curve.

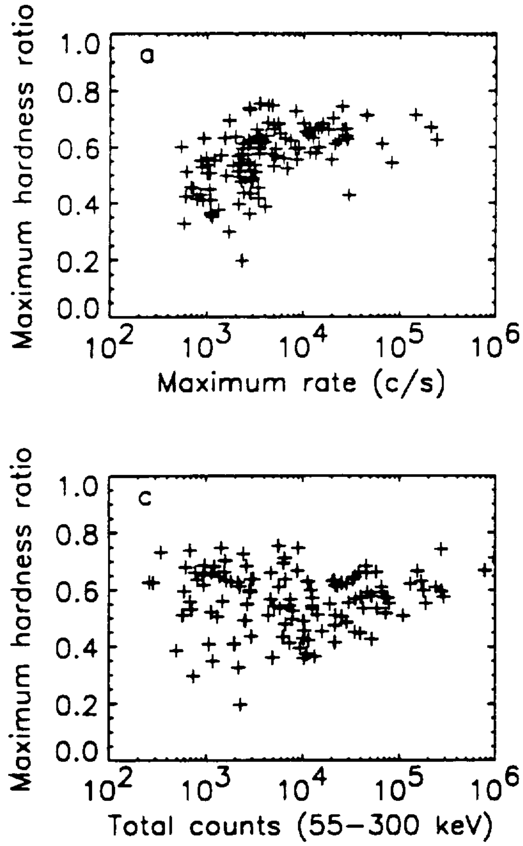

Figure 1. Scatter diagrams of hardness/intensity parameters for the total burst sample. *a*) $H_{\max}$ *vs.* $R_{\max}$, *b*) $\overline{H}$ *vs.* $R_{\max}$, *c*) $H_{\max}$ *vs.* $N_{\rm tot}$, *d*) $\overline{H}$ *vs.* $N_{\rm tot}$.

the subject of a previous study. Kouveliotou *et al.*[8] identified two separate subclasses of single events: events with short rise time ($\lesssim 1$ s) and long, approximately exponential, decay times also appeared to have hard spectra, whereas those events with more symmetric light curves had longer rise times and softer spectra. In our analysis we find that the average $H_{\max}$ and $\overline{H}$ for the former events are 0.72 ± 0.01 and 0.57 ± 0.01, respectively, whereas for the latter events the corresponding values are 0.55 ± 0.01 and 0.45 ± 0.01. We thus confirm the previous result[8] that the sharp rise/exponential decay events have harder spectra. The spectral/intensity correlation properties of these events are summarized in the third and fourth rows of Tables I and II. There is no evidence in either of these relatively small samples for a hardness/intensity correlation.

The last row of Tables I and II summarizes our analysis for the remaining events, *i. e.*, the longer events with more complex light curves. It is noteworthy not only that the correlation between hardness ratio and maximum rate is still evident in this subset, but also that the correlation between hardness ratio and total counts now appears marginally significant.

Table I. Correlation of Hardness *vs.* Maximum Rate					
		H_{max} *vs.* R_{max}		H *vs.* R_{max}	
	Number of Events	Correl. Coeff.	Chance Prob.	Correl. Coeff.	Chance Prob.
Total sample	126	0.51	< 0.0001	0.48	< 0.0001
Short spikes	30	0.23	0.25	0.20	0.30
Sharp rise, exp. decay	8	-0.025	> 0.5	0.035	> 0.5
Symmetric single peak	12	0.30	0.35	0.45	0.15
Others	76	0.52	< 0.001	0.44	< 0.001

Table II. Correlation of Hardness *vs.* Total Counts					
		H_{max} *vs.* N_{tot}		H *vs.* N_{tot}	
	Number of Events	Correl. Coeff.	Chance Prob.	Correl. Coeff.	Chance Prob.
Total sample	126	0.06	0.5	-0.16	0.2
Short spikes	30	0.15	0.45	0.023	> 0.5
Sharp rise, exp. decay	8	-0.36	0.40	-0.18	> 0.5
Symmetric single peak	12	0.28	0.40	-0.05	> 0.50
Others	76	0.36	0.002	0.23	0.03

DISCUSSION

Although our analysis methodology does not attempt to correct for instrumental effects, the raw DISCSC data are relatively free of instrumental biases and the observed correlation is not likely to be an instrumental artifact. The gain of the detectors is controlled automatically on-board using the 511 keV background feature. Pre-flight laboratory calibrations show no dependence of gain on count rate in the range of observed burst rates. The spectral response of the sum of the triggered detectors in the trigger energy range is relatively insensitive to the burst direction, and in any case the effect of not correcting for this response would be to smear out the data, making any real correlation less evident. Of course, the use of data properly corrected for instrumental response will always provide a more definitive test. Work to accomplish this is in progress.

Recent studies using data from other experiments[5,6] have also shown evidence for hardness/intensity correlations. Since our present sample is dominated by bursts too weak to be detected by previous instruments, we cannot yet directly confirm these results in the same range of burst intensities.

Mitrofanov *et al.*[6] suggest scenarios involving galactic neutron stars which might explain the data, either as two distinct populations or as a single evolving population. However, the galactic neutron star model is strongly constrained by the BATSE sky distribution and V/V_{max} measurements.[9] On the other hand, it has been noted[3] that the BATSE measurements are quite consistent with the bursts being extragalactic. Paczyński[4] has shown that at some level the cosmological redshift must produce a spectral/intensity correlation if the bursts are extragalactic, provided only that the spectrum is not a pure power law. In this case, the correlation should be more pronounced in BATSE than in previous experiments because BATSE samples weaker bursts. The different analysis methods applied to the other experiments[5,6] prevent any detailed intercomparison at this point. Further studies of these correlations may prove interesting in this context.

The fact that the subsets of short and single events show no clear correlation may be an indication that they represent a separate class. Unfortunately, the significance of this measurement is limited by the small sample sizes. Further studies will be undertaken when sufficiently large samples are available.

We find no significant difference between the maximum hardness ratio and the average hardness ratio as correlation parameters. In either case, however, the hardness is much better correlated with the maximum rate than the total counts. Since many previous studies have pointed out the susceptibility of fluence measurements to instrumental biases, we suspect that this is an instrumental effect.

SUMMARY

Even without corrections for detector response, the BATSE data show evidence for a correlation between spectral hardness and burst intensity, with the weaker bursts having softer spectra. The effect is most pronounced among the bursts which have long, complex light curves, although our ability to distinguish it among the other events may be limited by the sample size.

Although a spectral/intensity correlation may be accomodated in galactic neutron star models by increasing their complexity, it arises naturally from the cosmological redshift if the bursts are extragalactic. In any case, such a correlation must be considered in interpreting the burst size-frequency distributions.

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PRELIMINARY BURST LOCATION CALIBRATION RESULTS FOR THE BATSE INSTRUMENT ON CGRO

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ABSTRACT

Preliminary results pertaining to burst location using BATSE Large Area Detector measurements of solar flares are presented. These solar flare measurements are currently being used to fine tune the calibration of our data analysis software. The current status of techniques for identifying and eliminating systematic errors from the data analysis tools is discussed. Data revealing the effects of the atmospheric scattering algorithm that will be implemented in the data analysis software are presented.

INTRODUCTION

One of the ongoing BATSE calibration efforts is the optimization of the angular response of the Large Area Detectors (LAD's). The LAD angular response refers to the detector response as a function of the angle between the source direction and detector normal. Systematic errors in the detectors' angular response degrade the accuracy of the burst location algorithm. Part of the effort necessary for the reduction of the BASTE burst location systematic errors is the identification and elimination of inaccuracies in the LAD angular response.

PROCEDURE

In order to search for systematic errors in angular response (and other inputs to the data analysis software) a number of solar flares have been analyzed by calculating the direct detector response matrices for the known sun location. Matrices are also calculated for atmospheric scattering corrections based on a Monte Carlo simulation of photons scattering in the earth's atmosphere.

A power law fit is then performed on the three brightest detectors' data simultaneously using the calculated response matrices in the energy range from 44 to 229 keV across six channels. The ratio of the observed counts over the fitted counts is then calculated for each channel and for each detector. The same process is applied to the first,second and fourth brightest detectors' data as well.

RESULTS

Preliminary results of these fits are shown in figure 1 for the first energy channel showing the ratio vs. detector angle. The ratio of observed to fitted counts remains fairly constant out to about 60 degrees. After that the matrices consistently predict too many counts in the detectors seeing the flare edge on when compared to the detector seeing the flare face on. This result indicates that the direct response matrices should be smaller at large angles. A more thorough analysis of the flare data has been performed and a table of corrections to the large angle photopeaks of the LAD detector response matrices has been made. The correction is pronounced at the lower energies but fades at the higher energies. A larger sample of strong flares is being used to study this phenomenon and its effect on the burst location systematic errors.

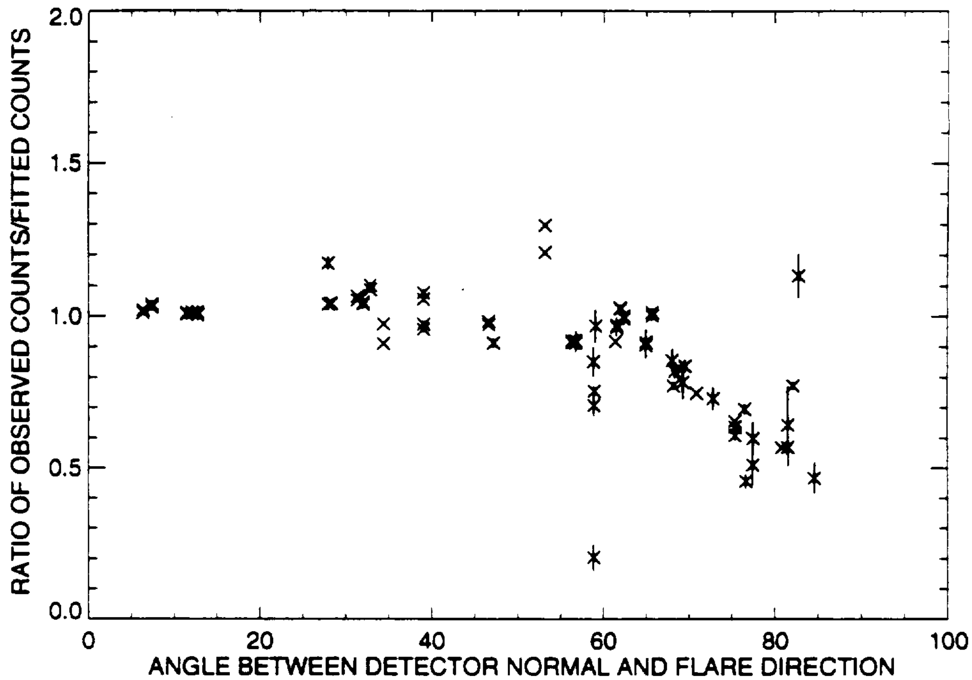

Figure 1. Ratio of observed to fitted counts vs. detector angle. The detector angle is the angle between the detector normal and the flare direction. The energy range is 44-60 kev.

Figure 2 shows the ratio of the observed counts to the total fitted counts including atmospheric scattering corrections vs. angle between the detector normal and the geocenter location (earth viewing angle). Here 0 is for a detector facing straight down and 180 is for a detector facing straight up. There is no strong correlation between earth viewing angle and detector response errors in this distribution. Those ratios significantly less than one restricted to large angular response angles in figure 1 show no obvious correlation with earth viewing angle in figure 2.

Figure 3 shows the ratio of the observed counts to the direct fitted counts only (not including atmospheric scattering corrections) vs. earth viewing angle. Here the fitted counts are somewhat underestimated when the earth viewing angle is small and the atmospheric scattering corrections are not applied.

Adding the large angle detector response matrix corrections and the Monte Carlo based atmospheric scattering correction routines to the burst location process should reduce the systematic errors significantly. The burst location procedure augmented with these corrections is being tested on a large set of solar flare data and independently located gamma-ray bursts.

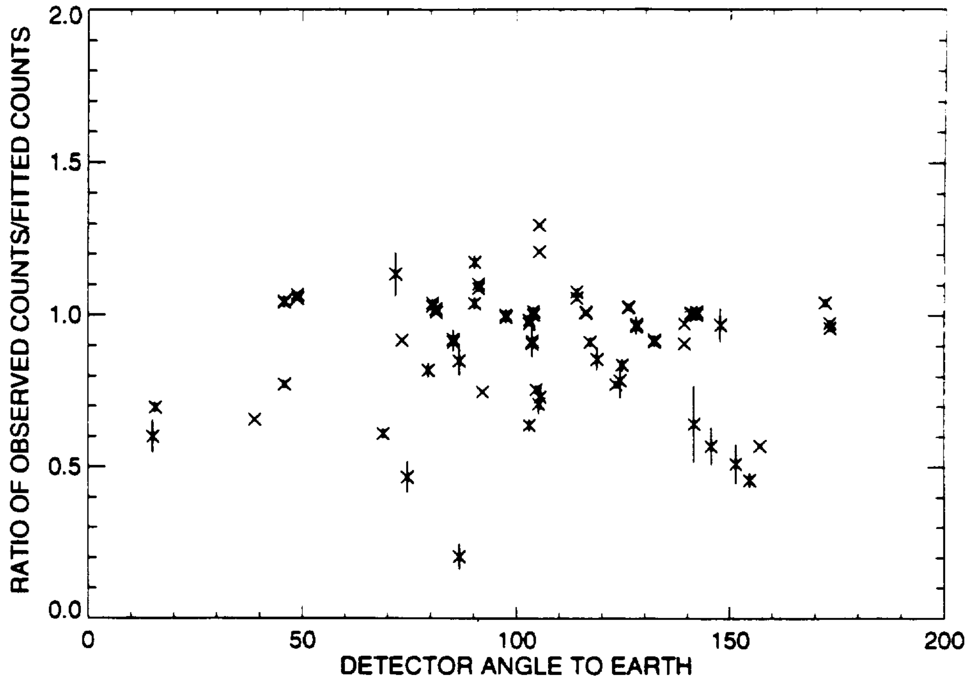

Figure 2. Ratio of observed to fitted counts vs. detector angle to earth. This is the angle between the detector normal and the geocenter location. The fitted counts here are corrected for atmospheric scattering. The energy range is 44-60 kev.

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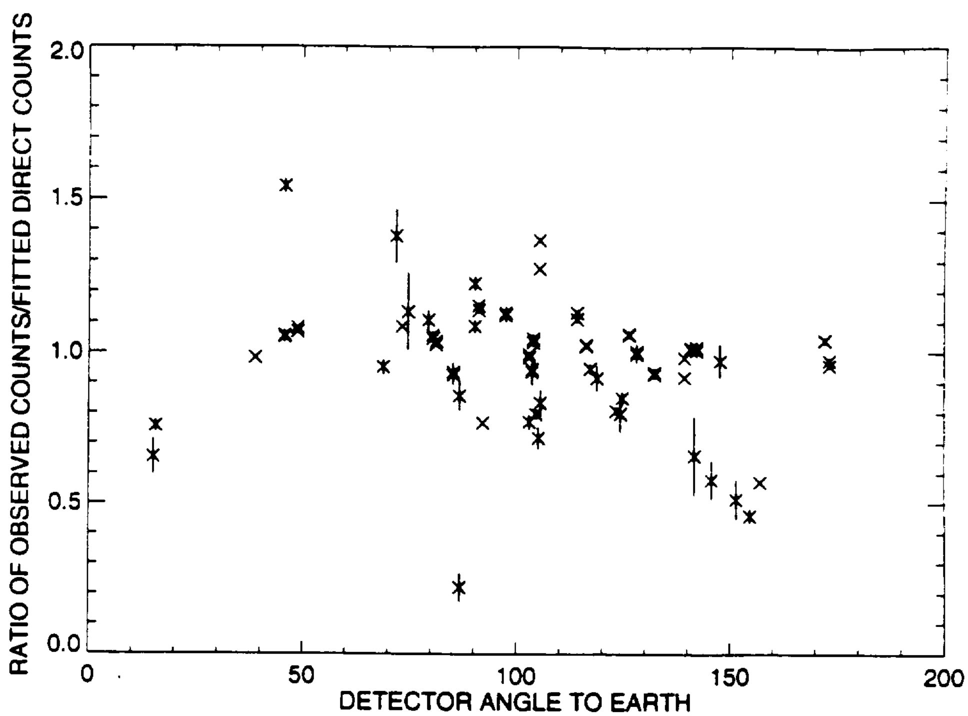

Figure 3. Ratio of observed to fitted counts vs. detector angle to earth. This is the angle between the detector normal and the geocenter location. The fitted counts here are not corrected for atmospheric scattering. The energy range is 44-60 kev.

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Studies of hard x-ray source variability using BATSE

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Abstract. — The BATSE large-area detectors on the Compton Observatory can be used to monitor the variability of x-ray and gamma-ray sources on timescales longer than a few hours using the Earth occultation technique. Spectral information is collected in 16 channels covering the energy range from ~25 to 2000 keV. Approximately 20 of the strongest sources are currently being monitored on a daily basis as part of standard BATSE operations. We discuss observations of the Crab Nebula, Cen A, and the Galactic Center as examples of the current BATSE capabilities.

Key words: X-rays: general – Gamma rays: observations – Methods: data analysis

1. Introduction

Though designed primarily as a sensitive detector of gamma-ray bursts, the Burst and Transient Source Experiment (BATSE) has useful capabilities as a near-all-sky monitor for other hard x-ray and low energy gamma-ray sources. Sufficiently bright persistent and long-term transient sources are detected using the Earth occultation technique (Paciesas et al. 1985; Fishman et al. 1990). During each *Compton* orbit, the Earth is seen by BATSE to sweep across a band in the sky extending ~35° above and below the orbit plane. As each source enters into (exits from) occultation by the Earth, count rates in the source-facing detectors decrease (increase) according to the source intensity. Although few sources are bright enough to show statistically significant single-occultation steps,[1] the sensitivity is greatly enhanced by combining data from many orbits. One of the first results using this technique was the discovery of an outburst of the recurrent transient GX339-4 (Fishman et al. 1991; Harmon et al. 1992).

In principle, the limiting sensitivity may be arbitrarily improved by including longer pre- and post-occultation background intervals and increasing the number of orbits accumulated. In practice, systematic errors due to source confusion, imperfect knowledge of background variations and detector response, and other effects are the effective limit on sensitivity. In the following sections we present preliminary results obtained from the occultation analysis and discuss their significance in the context of understanding systematic effects.

2. Instrumentation and Data Analysis

BATSE consists of eight identical modules located at the corners of *Compton*. The octahedral arrangement of the modules and the relatively thin (1.27 cm) large-area (~2,000 cm^2) NaI(Tℓ) detectors in each module are optimized for gamma-ray burst detection and localization. However, these same properties provide important capabilities for observations of other types of sources by detecting their coherent pulsations and/or by detecting their occultations by the Earth.

The occultation technique is presently being used for two complementary purposes during the daily BATSE quick-look scientific analysis. Firstly, a catalog of known bright source candidates is routinely used as input to software which calculates the source occultation times and fits a simple step function model with a polynomial background to the data at each occultation. In most cases, the separate occultation steps are summed on one-day timescales to produce a spectrum for each source. The results reported herein are derived from these one-day summations. Secondly, the data are also searched daily for occultation steps due to sources not included in the previous analysis. This approach is obviously necessary

[1] Cygnus X-1 and the Crab Nebula are the typical exceptions above 50 keV.

for detecting the transient outbursts from previously unknown or unsuspected sources. Once such a detection has been made, the software provides an approximate source location with which the intensity and spectrum of the new source are determined in the manner of the catalog sources. Additional details of the methodology are discussed by Harmon et al. (1992).

The analysis uses 16-channel spectra which are read out every 2.048 s for each detector. The energy widths range from ~one-half of the detector resolution at low energies to ~twice the detector resolution at high energies. This binning is convenient for use with model-independent spectral deconvolution techniques. The spectral results which we present below are obtained by simple inversion of the detector response. We have disregarded the lowest channel because of threshold effects and the highest channel because of calibration uncertainties.

3. Preliminary Results

The Crab Nebula is unique among hard x-ray sources as a standard reference because of its hard spectrum and effectively constant intensity. For occultation purposes it has the additional advantage of location away from other bright sources. We show in Fig. 1 the recent time history of the Crab flux as determined from occultation data. Deviations of ~10% from a constant intensity are evident in the figure. These appear to be due mainly to imperfect knowledge of the channel-to-energy conversion. Efforts to improve the channel-to-energy conversion algorithm are ongoing. Figure 2 shows our deconvolved Crab spectrum from the pointing interval spanning Truncated Julian Days (TJD) 8659–8672, compared with the HEAO-1 best-fit Crab spectrum (Jung 1989). The agreement with the HEAO-1 spectral shape is good, whereas the normalizations differ by ~10%.

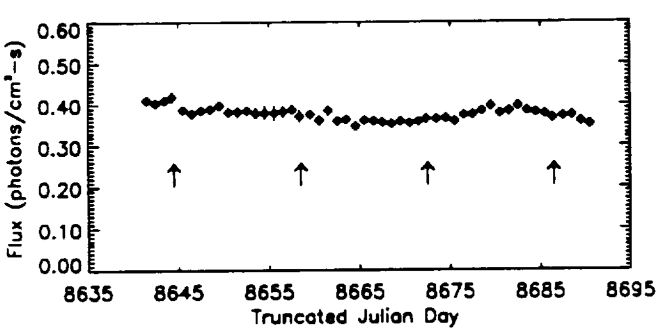

FIGURE 1. Crab Nebula flux measured by BATSE using the occultation technique. The energy range is 20–2000 keV. Arrows indicate times of spacecraft reorientation

The giant radio galaxy Centaurus A is a somewhat weaker source which is also located in a relatively uncrowded region. Figure 3 shows the measured raw count

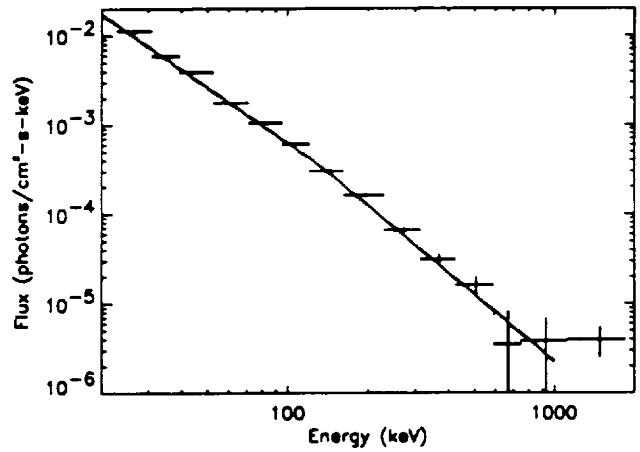

FIGURE 2. Crab Nebula spectrum for TJD 8659–8672. The data are deconvolved by inverting the detector response matrix. The solid line is the best-fit spectrum measured by HEAO-1 (Jung 1989)

rate from Cen A in the energy range 35–100 keV for an interval of ~50 days. During this interval the source appears to show relatively constant intervals of 5–10 days at a low intensity, interspersed with flaring episodes during which the intensity increases by as much as a factor of 4.

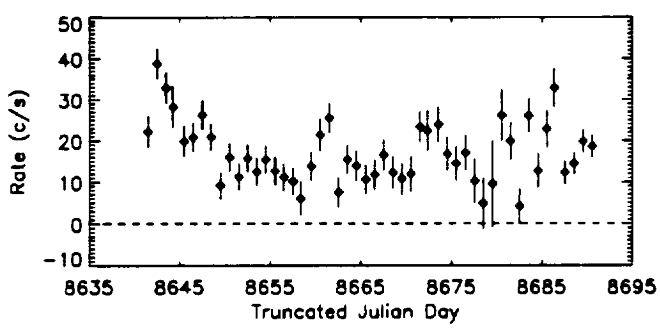

FIGURE 3. Cen A count rate history. The energy range is 35–100 keV

The Galactic center region presents one of the most difficult challenges for the occultation technique. SIGMA observations (Sunyaev et al. 1991) have shown that at least three variable sources contribute significantly to the hard x-ray flux from this region: 1E1740.7−2942, GX1+4, and GRS1758−258. The sources are located ~6° from each other, forming a roughly equilateral triangle. This separation is in principle large enough to allow the sources to be distinguished in the occultation analysis and the software computes fluxes for each of these sources separately. Nevertheless, confusion due to activity by other sources in the region is possible. Figure 4 shows raw rate histories of 1E1740 and GX1+4 during the same 50 day interval. 1E1740 shows a low but significant level of flux most of the time and an apparent strong outburst beginning around TJD 8680. Contemporaneous imaging observations by SIGMA (Schmitz-Fraysse et al. 1992; Gilfanov et al. 1992) indicate that 1E1740 was relatively constant but the nearby source GX 354-0 became active sometime between TJDs 8671 and 8682. The occultation geometry at this time was such that GX 354-0 cannot be clearly separated from 1E1740. We conclude that most or all of the outburst activity visible in our data during this interval is probably caused by GX 354-0.

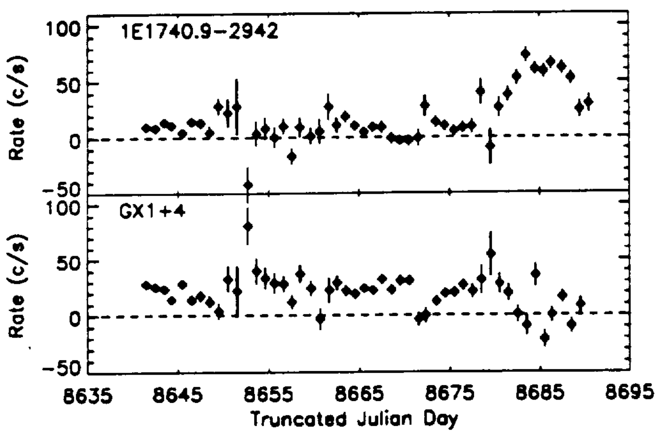

FIGURE 4. Count rates detected from two Galactic Center sources (35–100 keV). Larger error bars typically indicate times of source confusion

Figure 5 shows a spectrum of 1E1740 obtained during the lower intensity state. This is near our current sensitivity limit for a 14-day accumulation. The hard-state spectrum measured by SIGMA (Bouchet et al. 1991) in October, 1990, is shown for comparison. The BATSE data clearly lie below the SIGMA spectrum and are closer to the low-state of 1E1740 seen by SIGMA in the spring of 1991 (Sunyaev et al. 1991). Schmitz-Fraysse et al. (1992) report SIGMA observations of 1E1740 on TJDs 8670, 8674, and 8675 at a level of 45 mCrab which is consistent with the BATSE data in Fig. 5. Although these are not quite contemporaneous, Fig. 4 indicates that the BATSE measurements on those days do not differ significantly in intensity from the interval shown in Fig. 5. The BATSE data show no indication of the high-energy feature detected by SIGMA in October, 1990.

4. Conclusions

These preliminary results attest to the importance of BATSE as a sensitive near-all-sky monitor in the hard x-ray and low-energy gamma-ray range. Even in a crowded region such as the Galactic Center, it appears that the Earth occultation technique can be used to monitor the known bright sources and detect the occurrence of

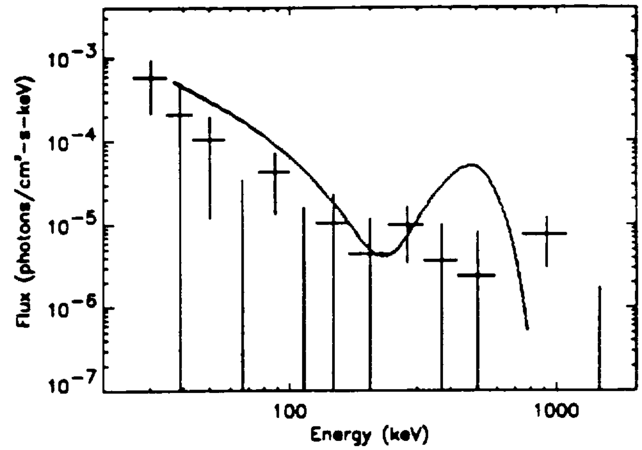

FIGURE 5. Spectrum of 1E1740.7-2942 during the interval TJD 8659–8672. The solid curve is the best-fit "hard" state spectrum measured by SIGMA in October, 1990 (Bouchet et al. 1991). The SIGMA "normal" state is essentially the same as the "hard" state below ~150 keV

anomalous behavior in the region. The efforts underway (Wheaton et al. 1992) to enhance the occultation technique should allow us to extend the BATSE monitoring capabilities to weaker sources as well as to reduce source confusion in crowded regions.

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15. Supplementary Notes

16. Abstract

Miscellaneous tasks related to mission operations and data analysis for the Burst and Transient Source Experiment on the Gamma Ray Observatory, to collection, analysis, and interpretation of data from the MSFC Very Low Frequency transient monitoring program, and to compliation and analysis of induced radioactivity data were performed. The results are summarized and relevant references are included.

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